Chapter 3
Fabrication of Ferroelectric Components and Devices

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Abstract The subject of this chapter is fabrication of ferroelectric components and microwave tunable devices based on them. The main methods of fabrication of ferroelectric components are considered including the single crystal growth and slicing techniques; bulk ceramic sintering; thick film, HTCC and LTCC technologies; chemical and physical deposition methods. The methods of fabrication of ferroelectric components are considered in association with structural characterizations which allows one to establish correlations between processing parameters and device performance. The basic principles and details of processing of devices utilizing ferroelectric components are given by examples of devices described in the Chap. 5. Special sections describe the general technology platforms of fabrication of microwave tunable devices based on thin films grown by chemical and physical deposition methods.

3.1 Introduction

In tunable microwave devices ferroelectrics are used in bulk (single crystal, ceramic) and film (thin, thick) forms. Different fabrication technologies are proposed in the past for bulk and film components. The single crystal ferroelectrics used in tunable microwave devices are grown by different methods. Due to the large sizes, relatively low defect density and lower cost the crystals grown by Verneuil method (MTI Corporation 2008, Semiconductor Wafer Inc. 2008, MaTecK GmbH 2008) are the most used in tunable microwave devices. The early tunable devices (Domenico et al. 1962, Johnson et al. 1962, Das 1964) use bulk ceramic processes.
HTCC, and especially LTCC processes are considered as the most cost effective processes. In some cases the HTCC process might appear preferable since it result in better crystalline structure in the grains. However, the selection of the metals for the electrodes (to withstand high temperature) is very limited. In this sense the LTCC is preferable and cost effective, although it requires careful selection of the additives lowering the sintering temperature (Jantunen et al. 2004). The surface roughness of the films is a common problem for thick film, HTCC and LTCC processes. Most of them use screen printing to pattern the films (ferroelectric, metal, and dielectric) which have resolution limitations. In the best case the minimum line width and slotwidth may be about 50 μm. In high volume production the line/spacing resolution, using screen printing methods, typically is about 100 μm. Narrower line/spacing (down to 20 μm) is achieved by using special thick film processes, e.g. photoimageable inks or etching. These processes need additional processing steps in production and suffer some limitations. A fine-line and high volume printing techniques for electronics applications, known as gravure printing, is developed by Microelectronics Laboratory, University of Oulu. The process allows 20 μm wide conductor lines with 50 μm pitch on LTCC and alumina with fired thickness up to 10–18 μm (Yeo et al. 2004, Hagberg et al. 2003). However, for smaller sizes the granular structure of the films and surface/interface roughness result in non-uniformity and sometimes even interruptions in ferroelectric films and metal strips and causes microwave loss and reliability problems.

Thin film processes based on the growth of ferroelectric films (PLD, RF magnetron sputtering, sol-gel etc.) combined with standard photo lithography processes of patterning, extensively considered recently, allow high spatial resolution and heterogeneous integration of agile ferroelectric components with other advanced technologies (like MEMs, micromachined cavities etc.), i.e. in line with the “More-than-Moore” concept promoted by ITRS. The PLD deposition of the ferroelectric films is a versatile/flexible process allowing experiments with different materials and compositions. However it is not cost effective when it comes to industrial processes used for large scale productions. RF magnetron sputtering and sol-gel processes are more useful for large scale commercial production. Recently combustion chemical vapor deposition (CCVD) is proposed (http://www.ngimat.com/technology/ccvd.html) as an alternative process for large scale production of tunable ferroelectric devices. Analysis of the published result shows that the best ferroelectric films in terms of density and low losses are produced by RF magnetron sputtering. Typically standard photolithographic processes are used for fabrication of microwave derives. In some cases the ferroelectric films are not patterned, in some cases wet or dry (ion milling) etching is used to remove the ferroelectric films where they are not needed.

Defects in crystal structure, like dislocations, point defects in the form of oxygen vacancies and background impurities may have significant effects on electric (conductivity) and dielectric (loss tangent) properties. For example, in high resistivity single crystal STO the stepwise changes (“switching”) in dielectric permit-